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# **UNIFORM PROJECT LONG SHOT**



PROJECT 1.01

Statement A

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GROUND AND WATER SHOCK MEASUREMENTS (U)

**GROUP-1**

Excluded from automatic  
downgrading and declassification.

J. D. Day, Project Officer

U. S. Army Engineer Waterways  
Experiment Station  
Vicksburg, Mississippi 39181

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DEPARTMENT OF DEFENSE  
WASHINGTON, D.C. 20301

Issuance Date: 19 April 1966

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## ABSTRACT

The objectives of this project were: (1) to measure and analyze the ground motions in the region above the detonation in light of effectiveness of containment and (2) to obtain ground-induced water shock measurements at close-in shoreline stations for possible correlations with injury to marine wildlife.

There were three distinct groups of instrumentation:

(1) downhole accelerometers and particle velocity gages, (2) surface velocity gages, and (3) water station gages. The recording equipment consisted of 3-kcps carrier systems, light-beam galvanometer oscillographs, and FM magnetic tape recorders.

Results were obtained from essentially all stations. Time-of-arrival information yielded a primary wave propagation of approximately 11,100 fps. Both the acceleration and velocity data indicated decidedly stronger motions than were predicted by previous data obtained from underground, contained shots. The data points to a possible yield of approximately 125 kt. Peak surface displacement at surface zero was 7.3 feet, occurring at 975 msec after detonation. Detailed data analysis for the final report is expected to give an indication of spall characteristics. Water pressures of approximately 20 and 7 psi

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were developed at slant ranges of 9340 and 27,320 feet, respectively.

From the preliminary data obtained, it was concluded that the weapon was successfully contained and that the water shock which was developed at the close-in shoreline station was insufficient to damage marine wildlife.

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## PREFACE

This report describes an experiment conducted by the U. S. Army Engineer Waterways Experiment Station (USAEWES) in connection with the Project .ot detonation, a part of the Vela Uniform Program which is directed by the Advanced Research Projects Agency (ARPA). The study reported herein was funded by the Defense Atomic Support Agency (DASA).

The work was conducted by personnel of the Nuclear Weapons Effects Division under the direction of Mr. G. L. Arbuthnot, Division Chief, and Mr. L. F. Ingram, Chief, Physical Sciences Branch. Project personnel were J. D. Day, Chief, Blast and Shock Section, who was project officer and author of this report, M. A. Vispi, and D. W. Murrell. L. T. Watson, F. P. Leake, and L. Sadler of the Instrumentation Branch, WES, assisted with the instrumentation and data recording. Col J. R. Oswalt, Jr. was Director of the WES, and Mr. J. B. Tiffany was Technical Director during this work.

The author gratefully acknowledges the assistance rendered by the WES Concrete Division personnel who supervised the instrument hole grouting, and Mr. Ralph Bendinelli who was the author of the Appendix of this report.

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## CHAPTER 1

### INTRODUCTION

#### 1.1 OBJECTIVES

The primary objectives of this project were: (1) to measure and analyze ground motions in the region above the detonation in light of effectiveness of containment and (2) to obtain ground-induced water shock measurements at close-in shoreline stations for possible correlation with injury to marine wildlife. A secondary objective was to compare and utilize (for protective structures purposes) the results of the ground motions with those obtained from other nuclear detonations in rock, e.g., Hardhat, Pile Driver, Salmon, and others.

#### 1.2 BACKGROUND

Project Long Shot a part of the Vela Uniform program directed by the Advanced Research Projects Agency (ARPA), studied detection and identification techniques for underground nuclear bursts. The Long Shot test consisted of an 80-kt nuclear burst detonated 2300 feet below ground surface on Amchitka Island in the Aleutian chain. Short- and long-range seismic measurements were made by other laboratories and agencies.

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The depth of burial was selected to avoid venting; nevertheless, earth motion measurements were needed in the region above the detonation and near the surface to assess the effectiveness of the containment. In addition, ground-induced water shock (pressure) measurements were needed in the near offshore regions for documentation of possible biological damage to marine wildlife.

### 1.3 THEORY AND PREDICTIONS

Free-field radial peak particle accelerations and peak particle velocities were determined from the composite curves of these parameters (Reference 1). These composite curves contain data obtained in salt, granite, tuff, and alluvium, scaled to 1 kt. For Long Shot, the granite data was used, scaled to 1 kt. One other adjustment was made to convert from granite to andesite (volcanic breccia), the primary geological formation of Amchitka Island. This conversion was made by considering the peak particle velocity ( $v$ ) to be proportional to seismic velocity, and peak particle acceleration ( $a$ ) proportional to the square of the seismic velocity. The following proportions hold:

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for granite;

$$v_g \approx c_g$$

and,

$$a_g \approx c_g^2$$

for andesite;

$$v_a \approx c_a$$

and,

$$a_a \approx c_a^2$$

Using the granite data points from Reference 1.

the adjusted values for andesite were computed as follows:

$$a_a = \frac{a_g c_a^2}{c_g^2}$$

and

$$v_a = \frac{v_g c_a}{c_g}$$

where:  $a_a$  = peak acceleration in andesite

$a_g$  = peak acceleration in granite

$c_a$  = seismic wave velocity in andesite

$c_g$  = seismic wave velocity in granite

$v_a$  = peak particle velocity in andesite

$v_g$  = peak particle velocity in granite

This data is plotted versus slant range in Figures 1.1 and 1.2. Table 1.1 lists the predicted peak values of the various parameters expected at each station. It is pointed out that the values used at the surface stations were doubled because many of the underground tests at the Nevada Test Site, in particular Hardhat (granite), have produced doubled surface

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motions; that is, double the free-field values.

The water pressure predictions were estimated as follows:

Values for stress versus distance for nuclear explosions in granite were obtained from Reference 2. Using these values, stress transmitted into the water was calculated by the following equation:

$$\sigma_t = \frac{2 \rho_2^2 c_2}{\rho_2^2 c_2 + \rho_1^2 c_1} \times \sigma_i$$

where:  $\sigma_t$  = stress transmitted into water, psi

$\sigma_i$  = incident stress in rock, psi

$\rho$  = density lb/ft<sup>3</sup>

$c$  = seismic velocity, ft/sec

Subscript (1) refers to rock, and (2) refers to water.

These values are listed also in Table 1.1.

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TABLE 1.1 PREDICTED VALUES

Station No.	Location	Slant range (ft)	Gage Type	Predicted values		
				a(g's)	v(fps)	p(psi)
1	EH-5	2300	A, V	10	11.6	-
2	EH-5	2200	A, V	11.4	12.4	-
3	EH-5	1800	A, V	10	8.6	-
4	EH-5	1600	A, V	14	10.5	-
5	EH-5	1400	A, V	21	13.0	-
6	EH-5	1200	A, V	36	16.8	-
7	EH-3	2375	V	9.2	11.0	-
8	EH-3	2281	V	10.2	11.8	-
9	EH-3	1890	V	8.8	8.0	-
10	EH-1	2544	V	7.4	9.8	-
11	EH-1	2450	V	8.2	10.4	-
12	EH-1	2100	V	6.4	6.7	-
21	Surface	3400	V	-	4.0	-
22	Surface	3400	V	-	4.0	-
23	Surface	3400	V	-	4.0	-
24	Surface	4610	V	-	2.0	-
25	Surface	4610	V	-	2.0	-
26	Surface	4610	V	-	2.0	-
27	Surface	6410	V	-	1.0	-
31	Cyril Cove	8660	V, P	-	0.6	145
32	Kirilof Bay	15,200	V, P	-	0.25	83
33	Constantine Harbor	27,800	V, P	-	0.10	44

A = accelerometer  
V = particle velocity  
P = water pressure

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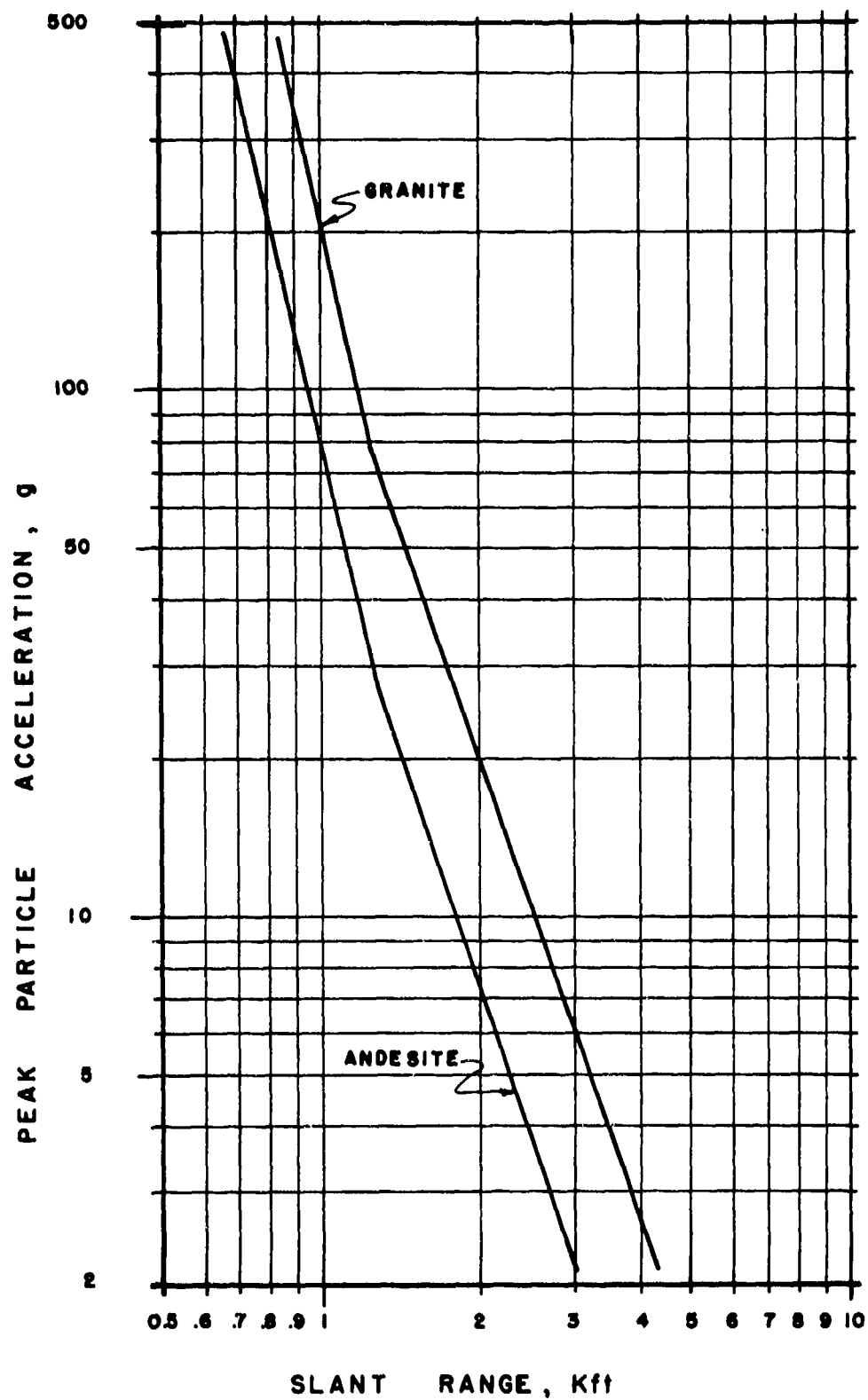


Figure 1.1 Predicted radial acceleration versus slant range.

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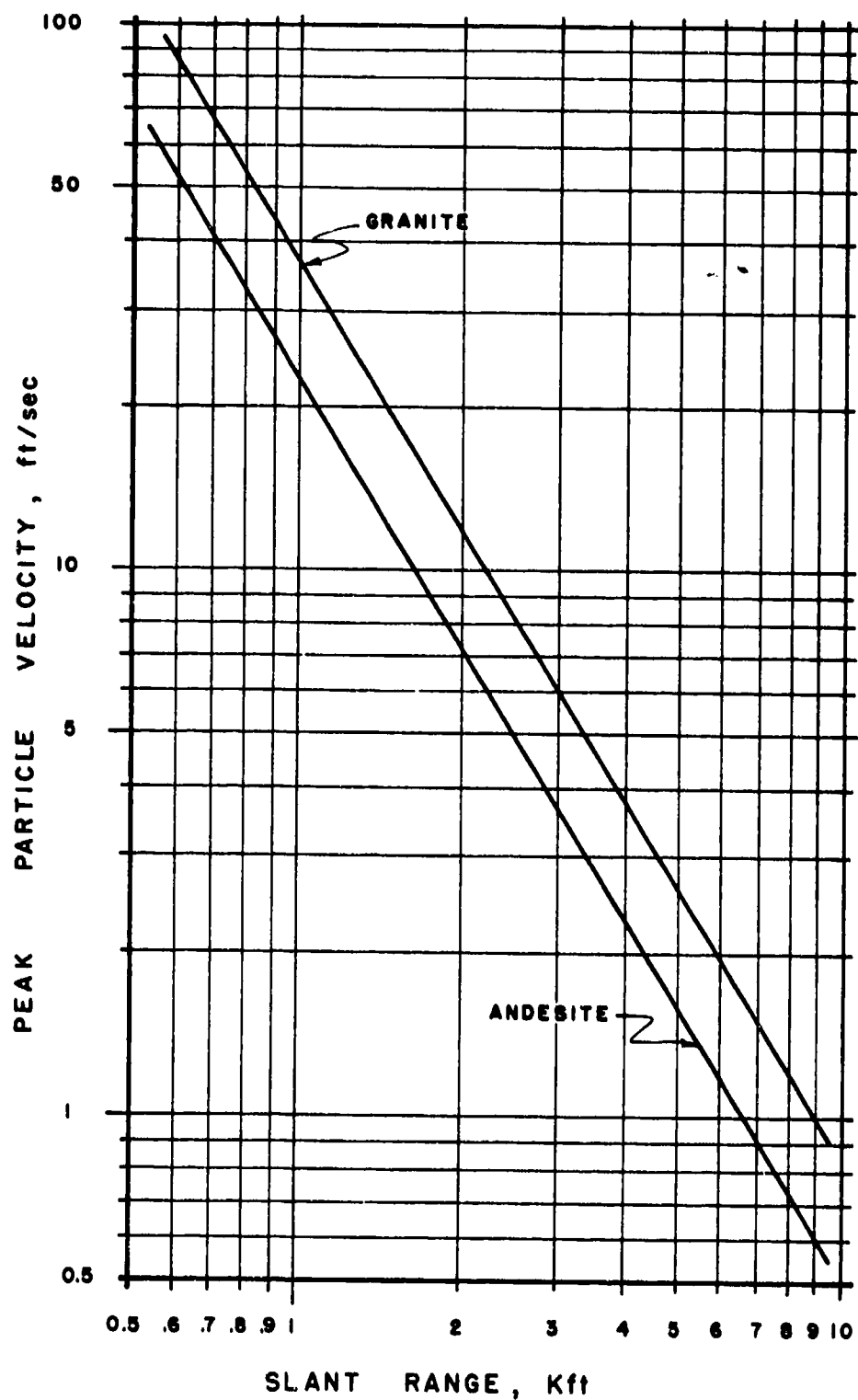


Figure 1.2 Predicted radial particle velocity versus slant range.

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## CHAPTER 2

### PROCEDURE

#### 2.1 OPERATIONS

This project was executed in two phases. Phase I consisted of the placement of the down hole or exploratory hole (EH) instrumentation in June 1965. Gages and supporting equipment, along with project personnel, were flown in to Amchitka on this early date in order that all drilling and grouting operations in the vicinity of the device emplacement hole could be completed. The emplacement hole effort was on the critical path and had to be started early.

Site activities during Phase I consisted of gage checkout and calibration, canister and gage train rigging, gage train placement, grouting, and final gage calibration and button-up. Project personnel then departed for the home station to finish preparation for Phase II, the final and most important task.

Phase II began during mid-August with equipment and personnel departing for the test site once more. Site activities consisted of surface and water station emplacements, along with instrumentation trailer checkout. Gages and recording equipment were given final calibrations and checkouts, and the entire electronic system was wired for remote



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operation from the Control Point.

### 2.2 INSTRUMENTATION

2.2.1 Gage Location and Layout. There were three distinct groups of instrumentation; first and most important were the exploratory hole gages. These were grouted in holes EH-5, EH-3, and EH-1, shown in Figure 2.1. These gages were encapsulated in specially designed, hermetically sealed, steel canisters (Figure 2.2). The six canisters for EH-5 contained a vertical particle velocity gage and a vertical accelerometer along with line-matching transformers and calibration relays. The three canisters each in EH-3 and EH-1 contained only vertical particle velocity gages with transformers and relays.

The next group of gages were the surface velocity gages. This group consisted of seven particle velocity gages which were mounted at the surface on steel channel beams which had been grouted into the surface rock, through the muskeg. The surface array is shown in the overall layout in Figure 2.3.

The final group of instruments consisted of the water station gages (Figure 2.4). There were three such stations, one located in Cyril Cove, one in Kirilof Bay, and the third in Constantine Harbor. Since all stations were alike, only

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one description will be given. The station consisted of a 4000-lb concrete anchor block sunk in approximately 60 feet of water with a gage support cable floating above it. From this cable, which was supported by four Marlex buoys, two electronic pressure-time gages were suspended 10 feet from the ocean bottom. In addition to these active gages, four passive ball-crusher peak-pressure gages were attached. A particle velocity gage was mounted on the anchor to complete the water stations.

2.2.2 Transducers and Calibrations. All electronic transducers were variable reluctance type. The accelerometers were Pace Engineering Company Model A18's with ranges between  $\pm 5$  to  $\pm 100$  g's and natural frequencies of 170 to 750 cps. These gages were viscously damped with silicone fluid to 0.707 of critical at 60<sup>0</sup>F. The accelerometers were calibrated in the laboratory on a rotary accelerator using increments of 20 percent of the predicted range to a final value of 140 percent. A calibration resistor was also impressed on the circuit at this time in order to relate a known electrical pulse to the physical calibration.

The velocity gages used the over-damped accelerometer principle. The gages employ a variable reluctance pickup

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to sense the motion of a small highly damped pendulum. The original gage design was by Stanford Research Institute. The model used on Long Shot was the Sandia Corporation Model DX which is a rather extensive revision of the original design.

The gages are oriented such that the pendulum swings freely when measuring horizontal motions. It is necessary to rotate the gages 90 degrees and use a small spring to support the pendulum when using this gage for vertical measurements.

The undamped natural frequency of the gages is 3.06 cps, and silicone fluid of 3000 centistokes viscosity was used to provide damping of 206 times critical at 60°F. The following relationships are given for the high- and low-frequency points at which the response is down 5 percent;  $w = 2n w_0/3$  (high frequency), and  $w = 3w_0/2n$  (low frequency), where  $w$  is the driving frequency,  $w_0$  is the undamped natural frequency, and  $n$  is the damping ration (related to critical damping). For these values of  $w_0$  and  $n$  the frequency response is essentially flat between 0.022 and 415 cps.

These vertical gages were calibrated by allowing the pendulum to fall through the damping fluid. With the gage oriented horizontally, an external magnet is used to pull

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the pendulum up against its stop (against the force of gravity and the spring). When the magnet is removed quickly, an acceleration equivalent to 2 g's is imposed on the pendulum by the spring force and the earth's gravitational field. As the pendulum moves through the damping fluid a record of the motion is made, the midportion of which is linear. The slope of the recorded trace represents a velocity of 2 times 32.2 ft/sec/sec or 64.4 ft/sec/sec. The electrical calibration signal is also recorded at this time for future scale factor determination.

The electronic water pressure versus time gages were Pace Engineering Company Model P24A. This gage has a flush stainless steel diaphragm which moves a small mass whose motion is sensed by a variable reluctance pickup. The gage pressure ranges were 0-200 and 0-500 psi. The natural frequencies ranged from 30 to 35 kcps. These gages were calibrated in the laboratory using compressed gas as a pressure source. An electrical calibration was performed in conjunction with the physical test.

The passive, ball-crusher, peak pressure gages were borrowed from the Naval Ordnance Laboratory, Silver Spring, Maryland. These gages use a piston to deform a 5/32-inch-diameter copper ball against an anvil. The deformation of

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this ball is related to peak pressure sensed by the gage. Calibrations were performed on this gage in the laboratory.

2.2.3 Installation. As was previously mentioned, the downhole gages were mounted inside steel canisters. These canisters were then fastened to each other at the proper spacings using swivels and wire rope. Instruments were protected inside by potting with an epoxy filler. Instrument cables were passed through the top of the canisters by means of a pressure-tight fitting and externally protected by means of a plastic conduit. This conduit is used primarily to protect the cable from the shock and stress until the transient data can be recorded. As the instrument train was connected, it was lowered down the exploratory hole. To provide ballast, an articulated, 600-lb weight or deadman was connected to the train and preceded the canister downhole. Once the train was in place, specially designed, density-matching grout was pumped into the hole to affix the gages and to seal the hole against possible venting.

Mounts for the surface velocity gages had to be intimately joined to the surface rock. If the gages had been allowed to float in the muskeg, this soft material would have behaved as a filter and possibly attenuated the primary

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ground motion; therefore, the gages were mounted on 6-inch steel channels driven and grouted 3 feet into the rock below the muskeg. The water station instrumentation was placed using a boat provided by the Defense Atomic Support Agency for a working platform. Despite high seas and inclement weather, the equipment was successfully placed on each station. Specially designed instrument cables from the gages were laid on the ocean floor and were weighted down with small concrete anchors placed at 100-ft intervals. To complete each station a particle velocity gage was bolted to the large anchor block.

2.2.4 Recording Instrumentation. The signal-conditioning system used 3-kcps carrier amplifiers and an oscillator power supply (which provides 3-kc excitation voltage). The data were recorded on light-beam galvanometer oscillographs operated at a recording speed of 160 in/sec. These data were also recorded on magnetic tape.

There were two recording sites. The data from the down hole gages, the surface gages, and the Cyril Cove and Kirilof Bay stations were recorded in the main trailer located 7500 SE of ground zero. A simple shock mounting system consisting of three tiers of tire casings sandwiched between plyboards

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was used. The trailer was placed on top of this mount and guyed with wire rope.

The recording instrumentation for Constantine Harbor was housed in a transportainer on the shore of the harbor. This station had its own power supply and was essentially independent of the main trailer. The 1-kcps timing signal used in the main trailer was hard-wired to the transportainer; zero time was furnished to both installations from the control point; thus, all recorders were synchronized.

### 2.3 DATA REQUIREMENTS

2.3.1 Description of Data. The primary data required by this project were close-in particle acceleration and particle velocity versus time. The other data required were water pressure versus time. The ball-crusher gages were used as backup instruments to obtain peak pressures in the event of failure of the electronic system.

2.3.2 Data Reduction. Data reduction performed at the test site consisted of manual readings of arrival times and peak amplitudes of gage signals. Data reduction and analysis for the final report will be made at the laboratory. This will consist of manual read-out, automatic digital conversion, single integration of the velocity and pressure data, and double integration of the acceleration data. These data will then be correlated with those obtained on other similar detonations and evaluated to determine the degree of scaling conformity.

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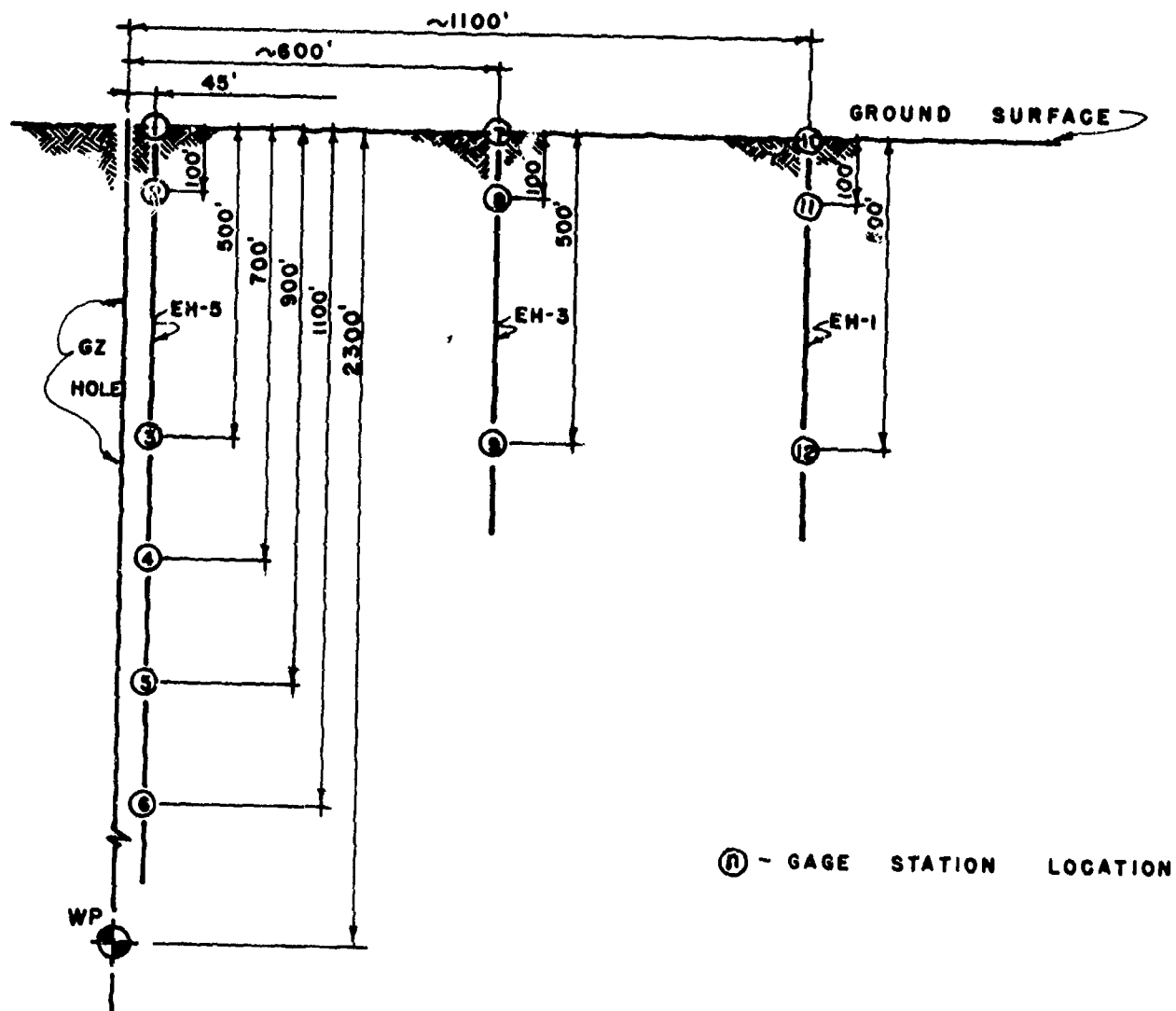


Figure 2.1 Downhole gage layout.

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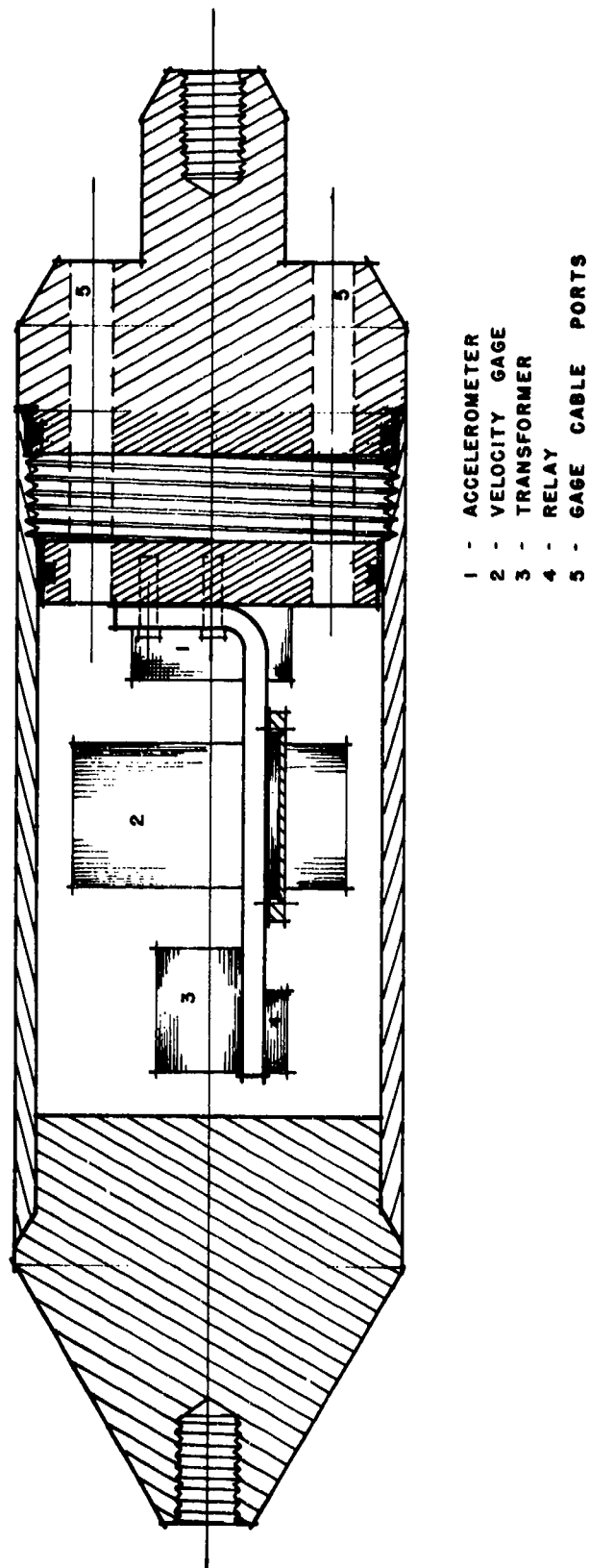


Figure 2.2 Typical downhole gage canister.

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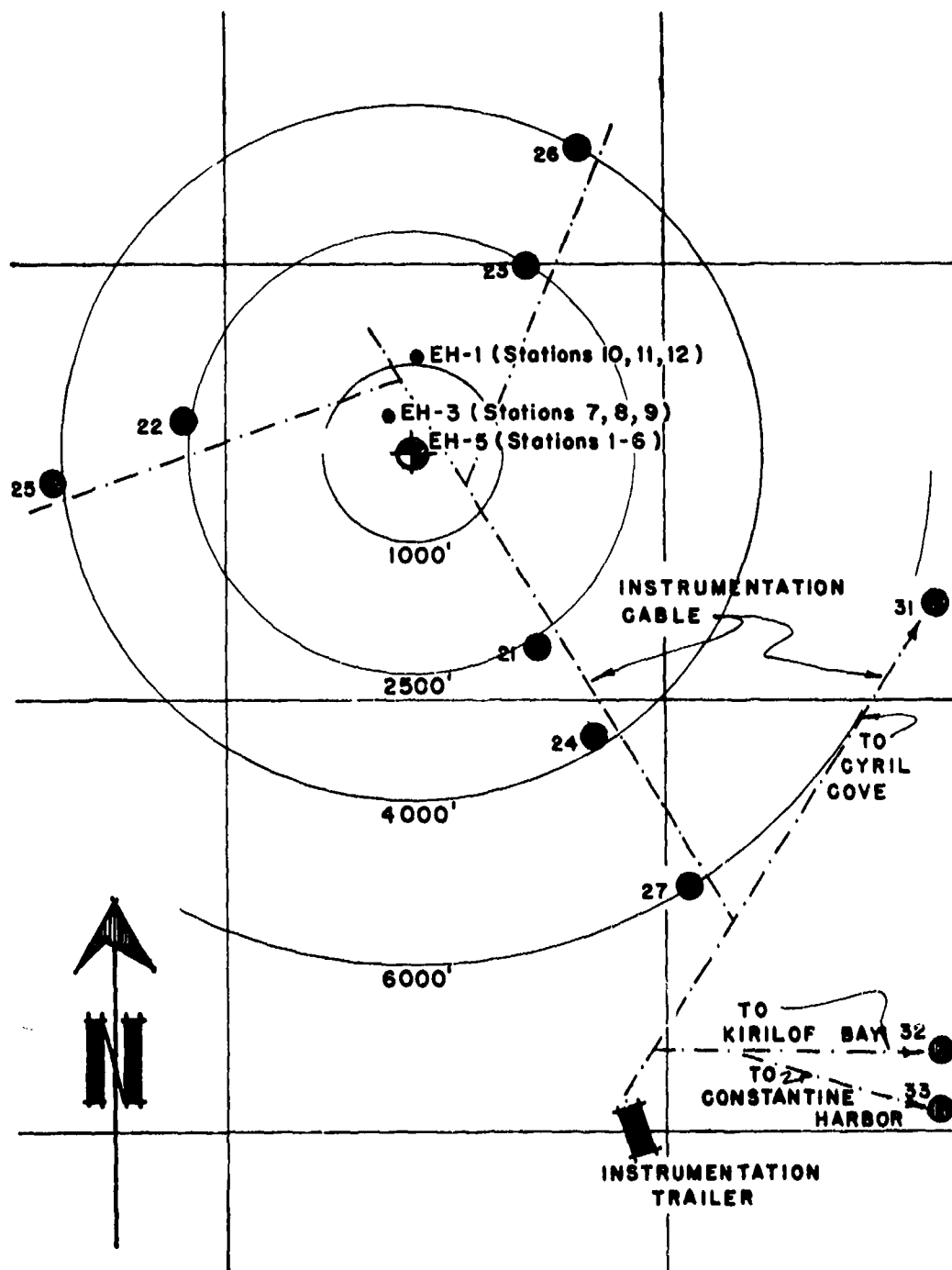


Figure 2.3 Surface gage layout.

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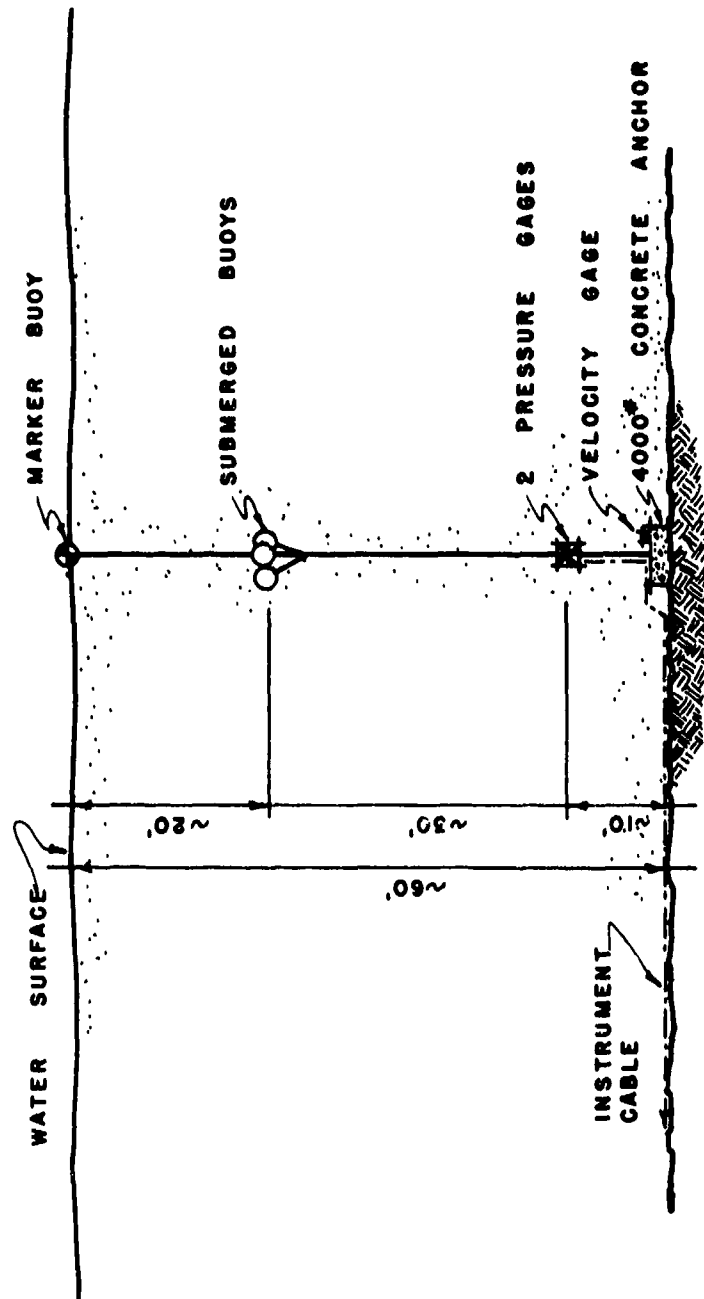


Figure 2.4 Typical water station array.

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## CHAPTER 3

### RESULTS AND DISCUSSION

The results presented in this interim report are preliminary, and discussion of these results is intentionally limited. Although the motions and pressures persisted for relatively long times, the data presented are, in most cases, the first significant transient peaks. One further step was taken with regard to the surface velocities, viz., a manual integration was performed to determine peak surface displacements.

Detailed analysis of the entire history of events will be made after all machine computations are finished. These analyses, which will attempt to define possible spall mechanisms, will be presented in the final report.

#### 3.1 INSTRUMENT PERFORMANCE

At shot time all recorders operated as programmed. All initiate signals were recieved, and zero (detonation) time was recorded on all recorders. The primary recorders, the oscillographs, performed adequately; however, of the three backup magnetic tape recorders, only one recorded properly. For reasons unknown at this time, two of the tape machines

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did not track properly during the shot, and consequently, no data can be retrieved from those tapes.

Good measurements were obtained from all motion gages, both surface and downhole. Even the gages closest to the device (1200 ft) survived long enough (23 msec) to record the peak values. Results at the water stations were not as successful, largely because of leakage brought about by severe wave action. Although no data were recorded at Kirilof Bay and the pond 2500 ft SE of surface zero, measurements of both particle velocity and water pressure were obtained from the Cyril Cove and Constantine Harbor stations.

The initial portions of the raw data as recorded are shown in Figures 3.1 through 3.4.

### 3.2 ARRIVAL TIMES

Arrival times were obtained for all stations where data were recorded (Section 3.1). These values are listed in Table 3.1 and plotted in Figure 3.5. This plot shows a fairly linear relation between arrival time and slant range; thus, the propagation velocity was essentially constant (11,100 ft/sec) over this distance interval. The average sonic velocity listed in the sonic logs obtained during the exploratory drilling was 11,000 fps for the breccia in the shot area. This value had been used in adjusting the granite data for making predictions (see Section 1.3).

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A high velocity (13,200 fps) was computed for the Constantine Harbor station. This value approximates that listed for the main andesite at shot depth (14,000 fps). This would indicate that the andesitic outcroppings noted at the Harbor are probably connected with that at the shot point. Moreover, the average propagation velocity should be larger at this distance (than for the closer-in stations), because the travel path is through a larger fraction of higher velocity material (the deeper strata).

### 3.3 PARTICLE ACCELERATION

All downhole gages in EH-5 failed at various times after onset of motion. The failures were probably caused by cable breaks (Figure 3.1). The cables from Stations 2 and 3 broke just after 300 msec. Since breaks had been expected, protective conduit had been used to prolong the recording time. This precaution proved to have been worthwhile.

All acceleration traces displayed a rather rounded waveform, and at Stations 1 and 6, noticeably flattened peaks of constant accelerations occurred. This latter type of waveform is characteristic of an overdriven amplifier; thus, the data were suspect. However, upon integration, the computed velocities agreed well with the measured velocities indicating realistic waveforms. Both the accelerometer and velocity traces at Station 4 exhibit anomalous forms.

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Figure 3.6 shows a comparison of measured and predicted peak accelerations. It can be seen that, although the values are different, the accelerations at the deep stations (where the free surface effect is not influential) exhibit a fairly constant deviation from the predicted values. This can also be stated as follows: although the measured attenuation of peak acceleration with distance agrees with the attenuation rate predicted, the measured magnitudes do not agree with predicted magnitudes which used the square of the seismic velocity as a parameter. The following reasons are offered as possible explanations for the higher-than-expected values: the coupling was better than expected. The yield was higher than originally estimated. The pretest yield value was listed at 80 kt, with a cube root of 4.3. A scale factor of 5 fits the measured data much better than 4.3, which would indicate a possible yield value approaching 125 kt.

It is evident from observation of the peak acceleration values in EH-5 (over the device) that the free-surface affects the motions at an appreciable depth. The peak accelerations decrease moving away from the explosion (upward) and then increase again as the surface is approached; the values at the near-surface stations are almost twice those at the deeper locations.

Some preliminary information concerning spalling can be determined from the accelerograms obtained above the shot.

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The trace from Station 1 (Figure 3.1) shows a second pulse occurring at about 36 msec after the first arrival. Using the pulse velocity from the arrival time calculations and assuming the second pulse is reflected from a spall gap arriving back at the surface, the spall gap would be located about 200 feet deep. The traces from Stations 1, 2, and 3 show multiple reflection after the first, probably indicating multiple spalls at various depths.

### 3.4 PARTICLE VELOCITY

Figure 3.7 shows peak particle velocity for all gages versus slant range. The majority of the data points are fitted with the dashed line. This line shows a constant deviation from the predicted curve similar to that of the acceleration data, i.e., the attenuation rate is as predicted, but the measured magnitudes are consistently higher than those predicted. Here again a yield root of 5 rather than 4.3 fits the data which points toward the higher yield value.

The higher values measured at the surface Stations EH-5, EH-1, 22-V, 24-V and 27-V demonstrate the free-surface effect. Several data points are low, which might have been caused by improper coupling or local fault lines. An attempt will be made to determine this during final analysis by close examination of seismic and drilling logs.



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### 3.5 SURFACE DISPLACEMENT

Peak vertical surface displacements obtained from integration of velocity records are plotted versus slant range in Figure 3.8. It should be noted that these data are maximum displacements as computed, with no attempt having been made to separate initial displacement prior to spalling and displacement due to free flight after spalling.

A check for symmetry of the surface displacement can be made by examining the data from Stations 21-27. Stations 21-23 were at a nominal slant range of 3500 feet, Stations 24-26 were at 4500 feet, and 27 was at 6300 feet. It is seen from Figure 3.8 that considerable higher motions occurred at Stations 21 and 24 than at the other two stations at similar slant ranges and that displacement at Station 27 was greater than at Station 25, which was closer in. This is significant in that Stations 21, 24, and 27 were all along a radial line extending southeast from SZ and is indicative of a symmetry in the gross surface motion and hence of the spalling zone.

Figure 3.9 shows ground surface profiles along the northeast and southeast lines at 300, 500, and 975 msec after detonation. With the exception of the surface station at EH-3 (600 feet from SZ), a possible pattern of surface rise and fall under spalling conditions is observed. The profile at the time of peak SZ displacement (975 msec) is a relatively steep cone, with the motions at 2500-foot ground range and beyond having

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occurred and subsided prior to this time. These profiles are exaggerated since the plot is on a grossly distorted scale.

### 3.6 WATER STATIONS

The peak particle velocity measured at the Cyril Cove was 1.04 ft/sec. Of the two pressure gages at this station, the low-range gage had been damaged by salt water before shot time. The high-range gage picked up the shock arrival, but because of probable low shock strength the output was extremely low. A preliminary value of approximately 20 psi is given at this time.

Figure 3.4 shows the pressure records from the two pressure gages (of different capacity and set range) and the velocity gage on the concrete anchor in Constantine Harbor. The wave shapes and amplitudes from the two pressure gages are in good agreement. The pressure signature was oscillatory in nature with a frequency of roughly 10 cps and maximum pressure change of about 7 psi. It is interesting to note that the particle velocity has the same wave shape but is  $90^{\circ}$  out of phase with the pressure. This may be explained as follows: if it is assumed that the ground motion causes the pressure wave in the water, then the pressure should be proportional to the acceleration of the ground. Since acceleration is the rate of change of particle velocity, the pressure (and the acceleration) will be zero at each maxima and minima (peak) of the particle

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velocity. It can be seen from the records that the pressure is at ambient level (equivalent to the static head) at the times that the particle velocity peaks, both positive and negative.

It is also interesting to note that no shocks were observed in the water. This is to be expected because of the oblique geometry of the ground wave arrival at this distant station and the relatively long rise time of the ground motion. Although the arrival time of this disturbance at Constantine Harbor would seem to indicate a compressional wave, additional analysis is needed to determine the nature of this surface wave.

As was stated before, no data were obtained from the Kirilof Bay and close-in stations. The ball-crusher gages were retrieved from all stations except Constantine Harbor; however, because of the low pressures, no discernible indents were observed on the balls. These gages were not designed to measure pressure levels as low as those prevalent during this test.

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TABLE 3.1 SUMMARY OF RESULTS

Station Number	Location	Slant Range ft	Arrival Time msec	Peak Value	First Peak Rise Time msec	Peak Surface Displacement ft	Time From Arrival msec
1-A	EH-5 Surface	2300	202	18.69 g	18		
1-V	"		205	18.7 fps	30	7.3 ft	765
2-A	EH-5 100'	2200	191	25.2 g	19		
2-V	"		194	12.7 fps	50		
3-A	EH-5-500'	1800	153	24 g	14		
3-V	"		156	15.6 fps	22		
4-A	EH-5-700'	1600	133	22.4 g			
4-V	"		134	18.2 fps	25		
5-A	EH-5-900'	1400	115	41+g	10		
5-V	"		117	25.8 fps	20		
6-A	EH-5-1100'	1200	97	50+g	12		
6-V	"		98	28.8 fps	20		
7V	EH-3 Surface	2375	210	10.1 fps	40		550
8V	EH-3 100'	2281	201	13.0 fps	59		619
9V	EH-3 500'	1890	160	12.0 fps	36		-
10V	EH-1 Surface	2544	232	13.4 fps	38		480
11V	EH-1 100'	2450	218	9.2 fps	51		451
12V	EH-1 500'	2100	181	5.96 fps	23		-
21V	2500' SE Surface	3496	311	7.9 fps	48	1.01 ft	236
22V	" W	3525	322	7.8 fps	51	.71	171
23V	" NE	3385	300	4.78 fps	45	.6	230
24V	4000' SE	4483	400	3.94'fps	46	.4	190
25V	" W	4758	423	2.01 fps	51	.16	157
26V	" NE	4594	417	2.87 fps	48	.26	160
27V	6000 SE	6320	559	2.73 fps	46	.17	120
31V	Cyril Cove	9340	826	1.04 fps	60	-	-
31P <sup>1</sup>	"			20 psi	-	-	-
32V <sup>1</sup>	Kirilof Bay	15200	No record				
32P <sup>1</sup>	"						
32P <sup>2</sup>	"						
33V	Const. Harbor	27321	2070	0.04 fps	77		-
33P <sup>1</sup>	"			6.9 psi	-		-
33P <sup>2</sup>	"			7.6 psi	-		-
34P <sup>2</sup>	Vofw Pond	3400	No record				

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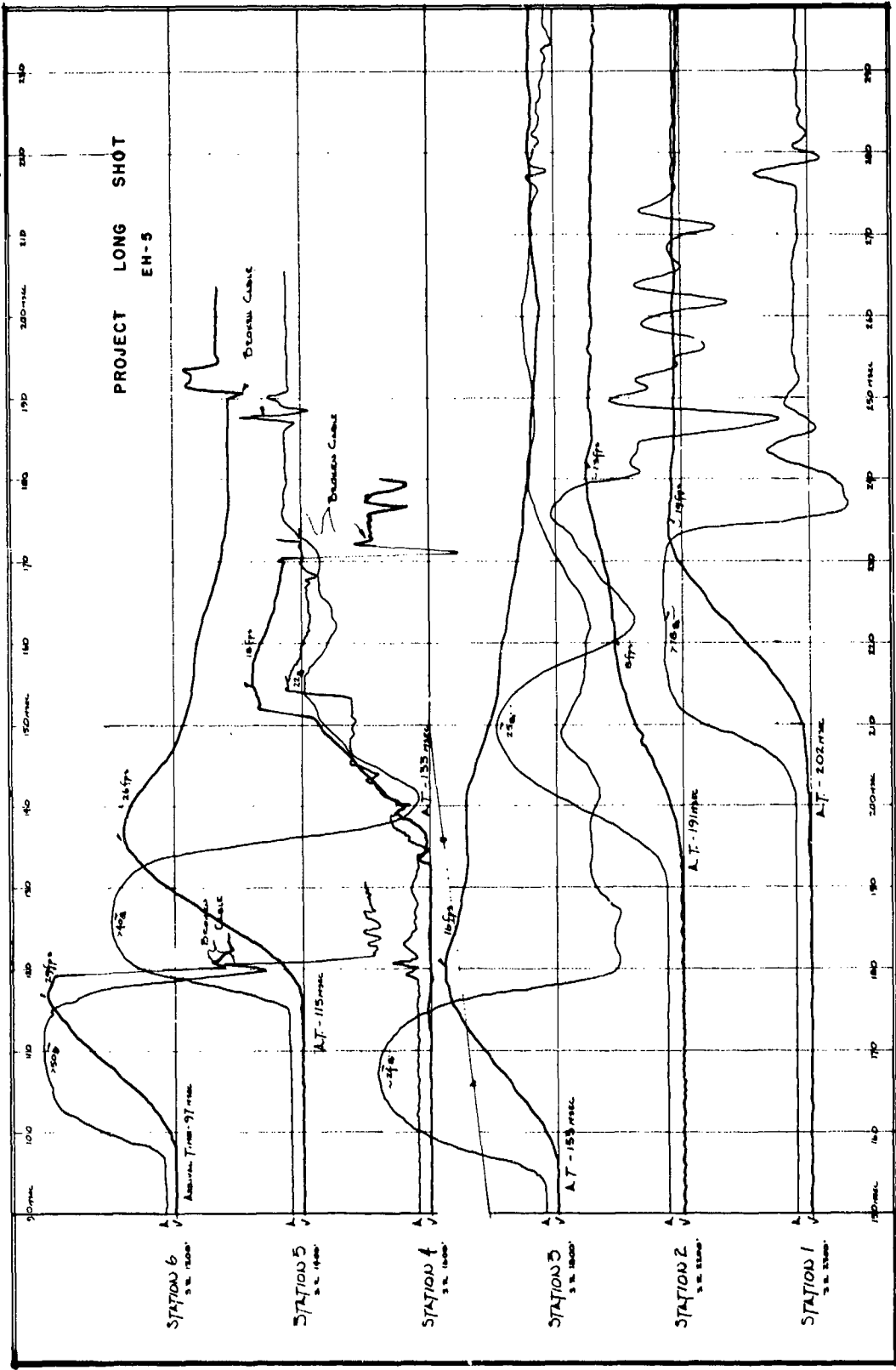


Figure 3.1 Raw data, EH-5.

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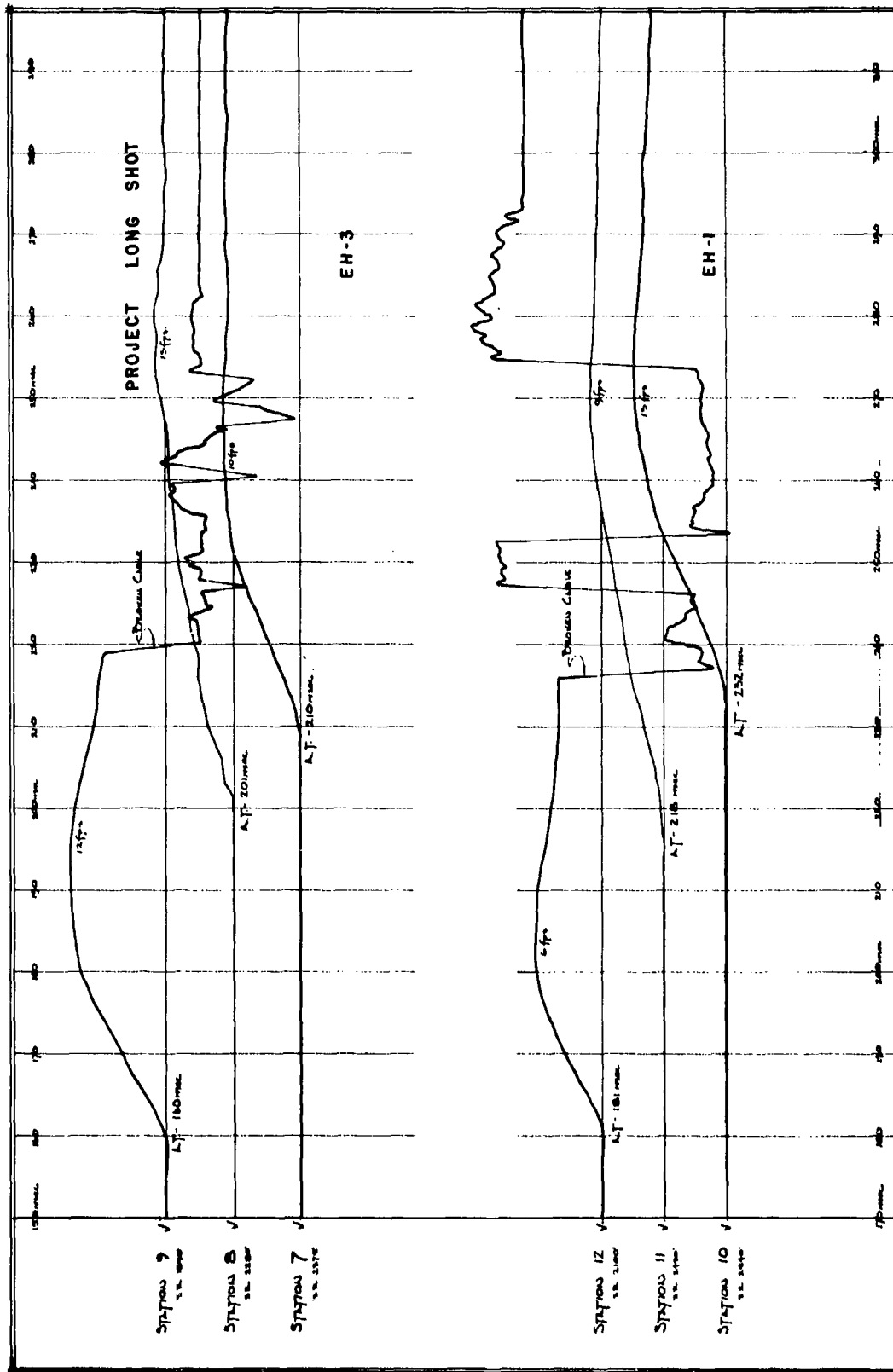


Figure 3.2 Raw data, EH-3 and EH-1.

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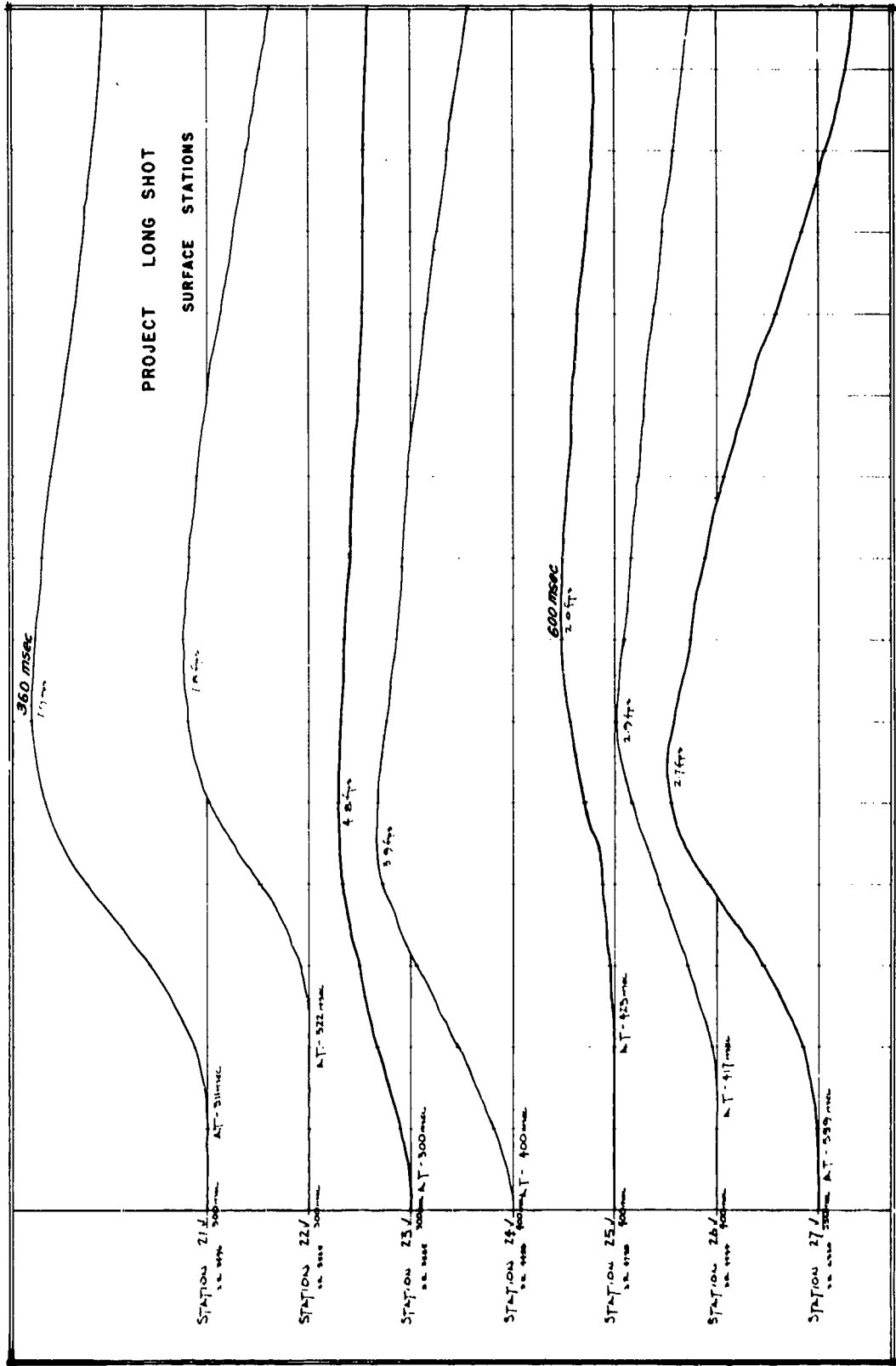


Figure 3.3 Raw data, surface stations.

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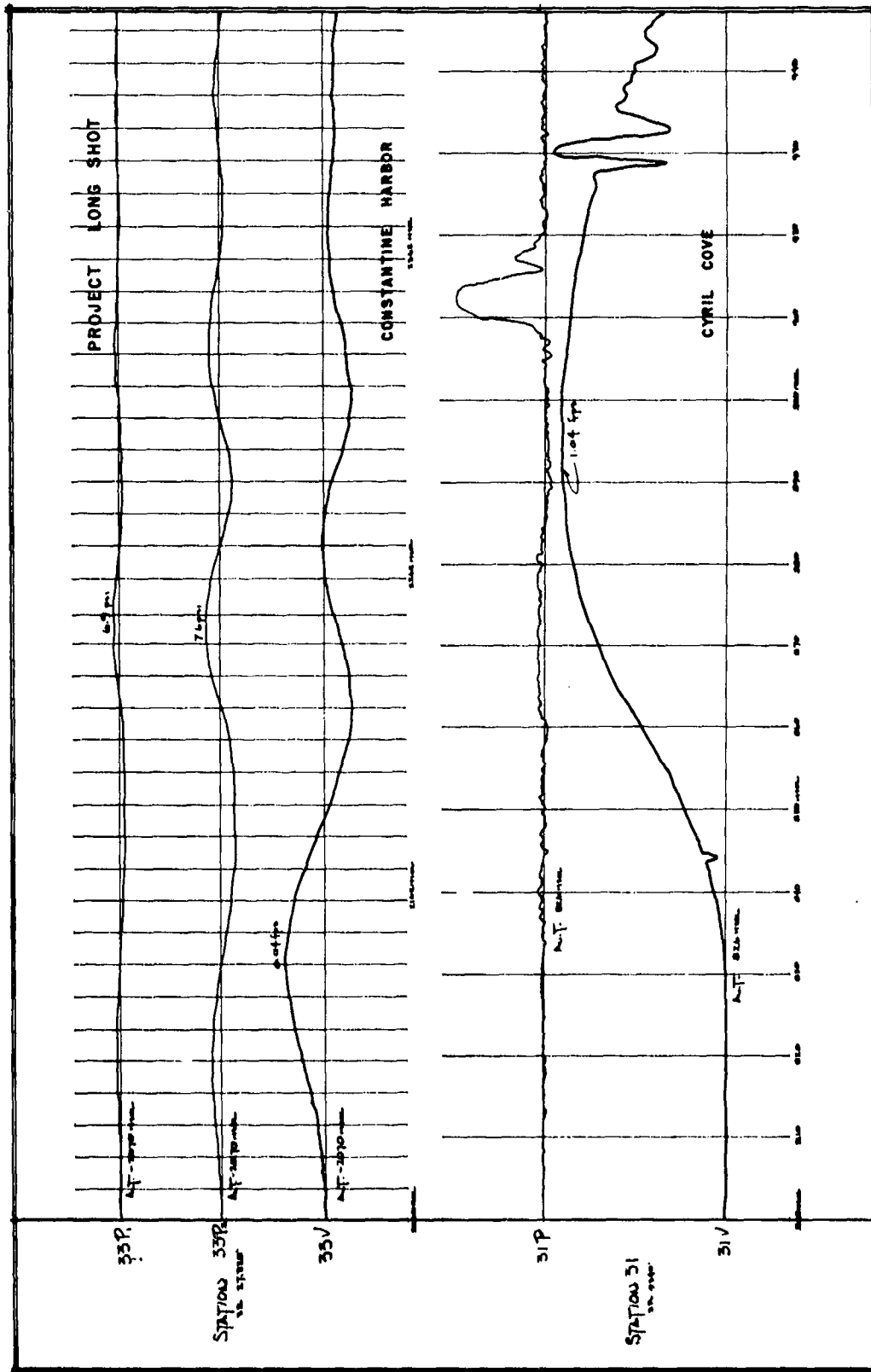


Figure 3.4 Raw data, water stations.

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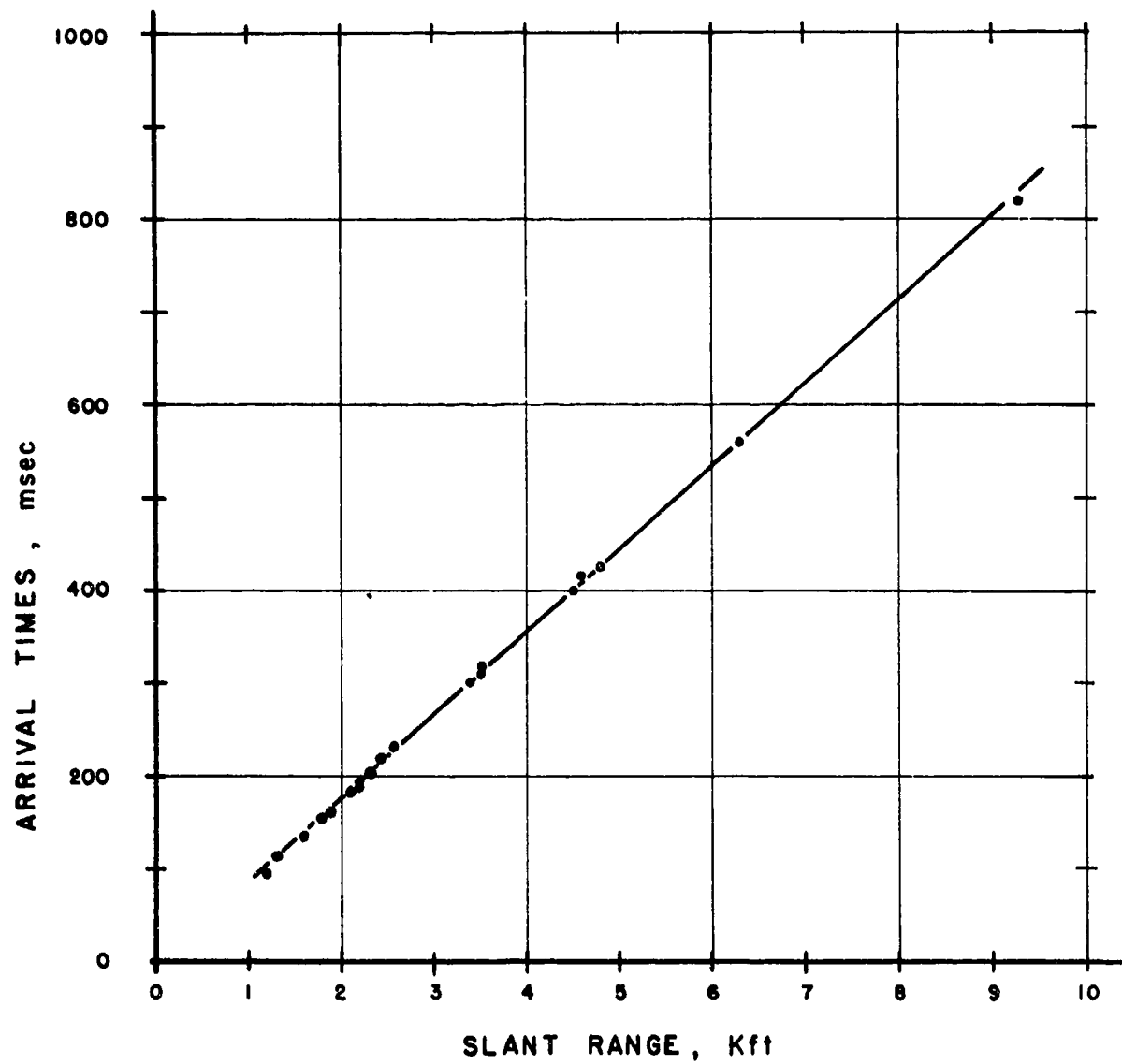


Figure 3.5 Arrival time versus slant range.

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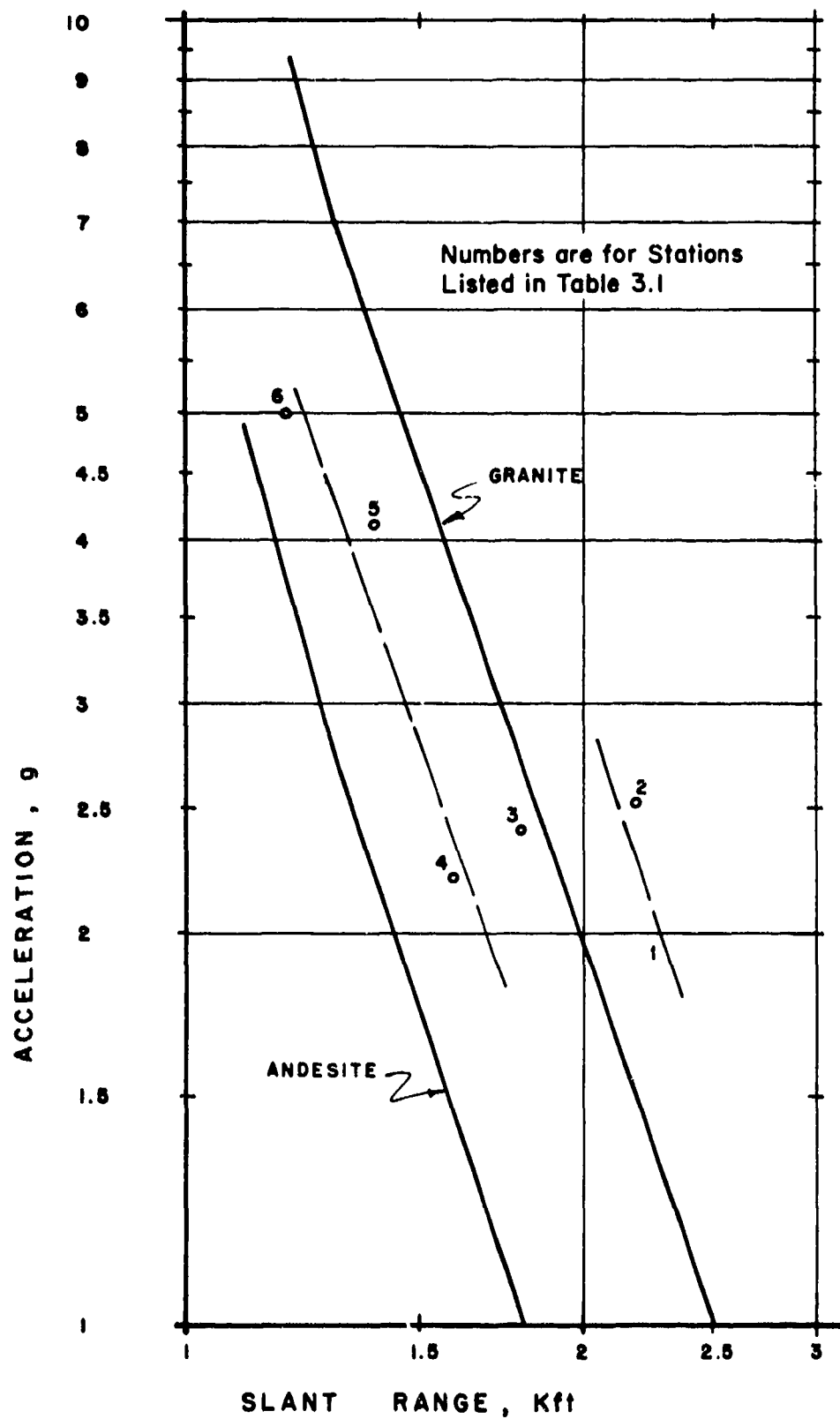


Figure 3.6 Measured acceleration versus slant range.

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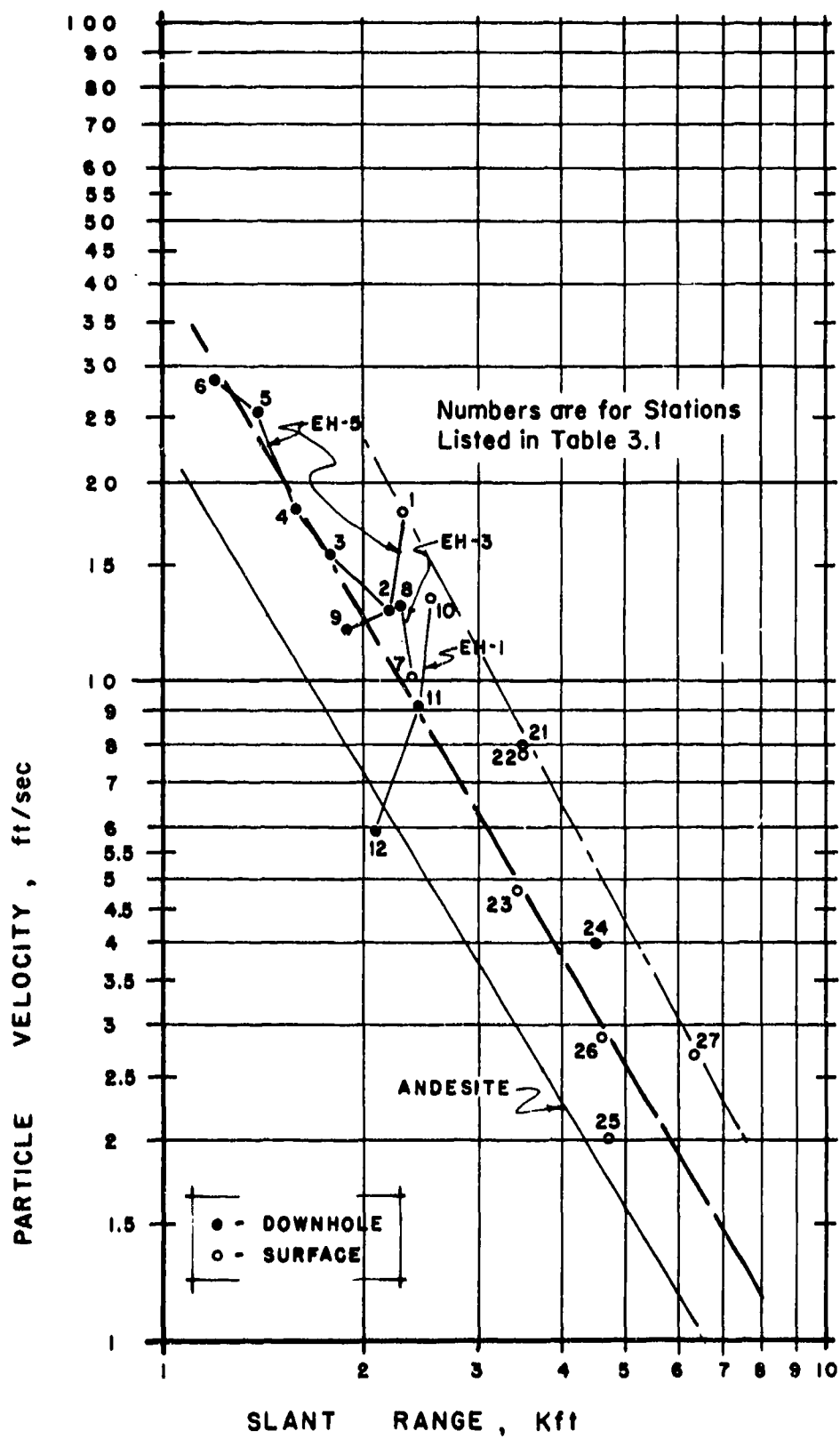


Figure 3.7 Measured particle velocity versus slant range.

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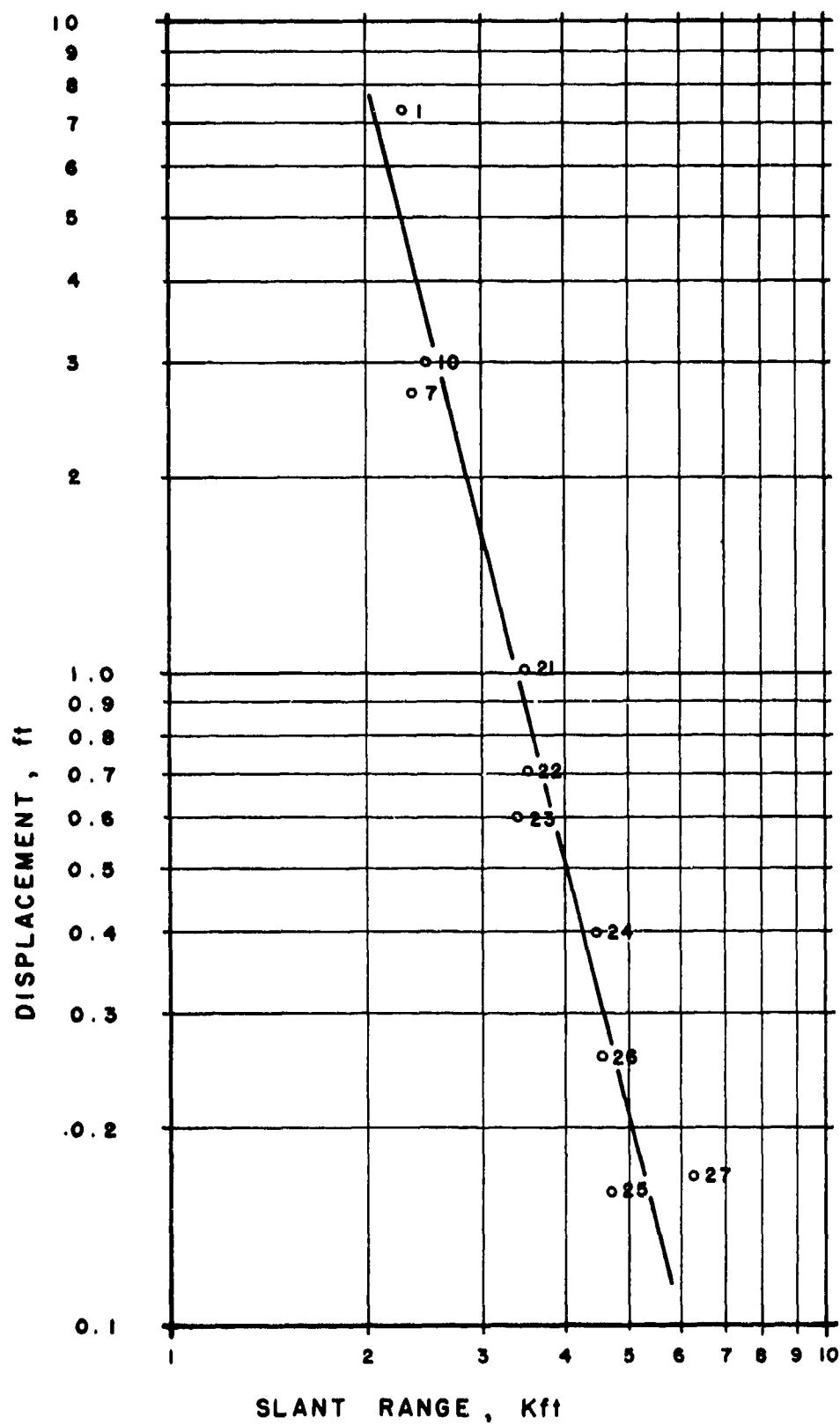


Figure 3.8 Peak surface displacement versus slant range.

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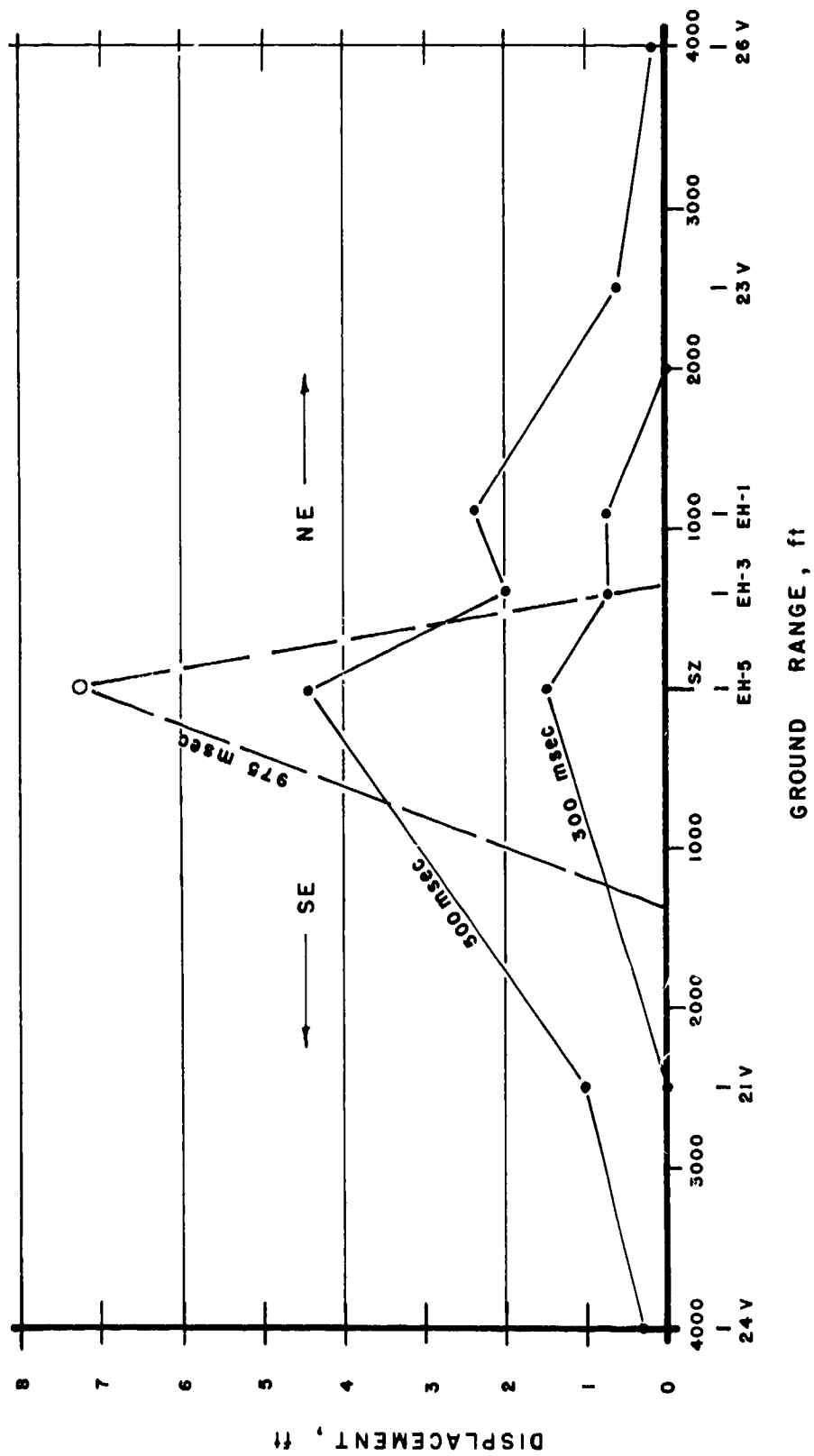


Figure 3.9 Varying surface profiles versus ground range.

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## CHAPTER 4

### CONCLUSIONS

Project objectives were realized in that excellent earth motion and water pressure measurements were obtained. The following conclusions are made at this time:

a. When comparing Long Shot ground motions with previous empirical data from nuclear bursts, it is concluded that there was better ground shock coupling to the andesite than to granite, or the yield was considerable larger than 80 kt.

b. Despite a peak transient displacement of more than 7 feet at ground zero, the containment was complete.

c. Pressure induced into the water by ground motions at Constantine Harbor was not sufficient to kill (or apparently seriously injure) sea otters. (Research at Lovelace Foundation on biological damage to animals has shown rise time to be important as well as pressure. Both the rise time and pressure amplitudes were favorable for the Long Shot test.)

d. It is tentatively concluded that a pressure of about 20 psi (with an undetermined rise time) was not injurious to marine life in Cyril Cove.

Additional data reduction and analyses are required to study possible spall effects.

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## APPENDIX INSTRUMENT GROUTING

### A.1 PURPOSE

A grout mixture was required which would when hardened match as closely as possible certain in-situ physical properties of the subsurface formation at the project site. The instrumentation described in this report was to be emplaced in drilled holes and coupled to the formation by grouting.

The criteria for the grout design was based on the results of physical tests performed on core specimens obtained from instrument hole EH-5.

### A.2 CURSORY EXAMINATION OF CORE

A cursory examination of the cores revealed the following:

	CD Ref No.	Sample No.	Core Size	Description
70.0	LS-3 DC-1(A)	15B	2-5/8 in.	Conglomerate, greenish gray composed chiefly of volcanic agesta. The matrix appears to be partly composed of a brownish clay and is slightly calcareous. Particles range from clay size to 1-1/2 inch.
71.0				
316.4	DC-1(B)	14C	2-5/8 in.	Conglomerate (lapilli tuff), greenish gray, matrix is partly composed of a brownish clay and is slightly calcareous. The core is badly weathered and crumbles in the hand. Particles range from clay size to 1/2 inch.
317.7				
319.9	DC-1(C)	14B	2-5/8 in.	Same as above core.
320.8				

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	CD Ref No. LS-3	Sample No.	Core Size	Description
888.7	DC-1(D)	12B	2-1/2 in.	Conglomerate (lapilli tuff), light greenish gray, matrix is clayey and is slightly calcareous. The core is badly weathered and altered and crumbles in the hand. Particles range from clay size to 1/2 inch. Conglomerate (tuffaceous gray-wacke sandstone), greenish gray, has clay present which is slightly calcareous. Fragments range from clay size to 1/4 inch.
889.7				
1191.5	DC-2(A)	11A	4 in.	
1192.5				
1282.9	DC-2(B)	10A	4 in.	Same as above core.
1283.5				
1283.5	DC-2(C)	10B	4 in.	Same as sample No. 11A.
1284.5				
1704.5	DC-1(E)	8C	2-1/2 in.	Conglomerate (tuff), greenish gray, very fine grained.
1705.5				
1709.3	DC-1(F)	8A	2-1/2 in.	Same as above core.
1710.2				
2132.7	DC-1(G)	6A	2-7/16 in.	Conglomerate, greenish gray, similar to sample No. 15B.
2133.7			No scale	



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### A.3 RESULTS OF PHYSICAL PROPERTIES TESTS OF CORES

The following are the results of compressive strength, ultrasonic pulse velocity, and specific gravity tests of selected core specimens:

<u>Core No.</u>	<u>Compressive Strength, psi</u>	<u>Specific Gravity</u>	<u>Unit Weight lb/cu ft</u>	<u>Ultrasonic Pulse Velocity, fps</u>
LS-3 DC-1(A)	3860	2.27	141.4	6,100
LS-3 DC-1(D)	2260	2.29	142.7	6,205
LS-3 DC-2(A)	3390	-	-	-
LS-3 DC-2(B)	4950	-	-	-
LS-3 DC-2(C)	5260	2.36	147.0	10,645

### A.4 GROUT MIXTURE MATERIALS

Following a series of preliminary mixture proportioning studies using combinations of various grouting materials, the final mixture was proportioned using the materials noted below:

<u>Material</u>	<u>Specific Gravity</u>	<u>Unit Weight Solid, lb/cu ft</u>
Cement, Type I	3.15	196.24
Fly Ash	2.46	153.26
Sand, Magnetite	4.94	307.76
Gel, Bentonite	2.36	147.03
Water	1.00	62.3

### A.5 GROUT MIXTURE PROPORTIONS

<u>Material</u>	<u>Materials Proportions for a 1-Bag Batch</u>	
	<u>Solid Volume, cu ft</u>	<u>Dry Batch Weights, (SSD)*</u>
Cement, Type I	0.335	65.74
Fly Ash	0.144	22.07
Sand, Magnetite	0.325	100.00
Gel, Bentonite	0.018	2.65
Water	0.846	52.69

\*Saturated, surface-dry weights

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### A.6 PHYSICAL PROPERTIES TESTS OF GROUT SPECIMENS

The results of the hardened physical properties tests performed on grout specimens cast from the grout mixture developed in the laboratory were as follows:

<u>*Test</u>	<u>Age, 28 days</u>
Compressive strength, psi	3100
Specific gravity	2.34
Unit weight, lb/ft <sup>3</sup>	146
Ultrasonic pulse velocity, fps	10,300

\*Test results represent the average value of three each 3- by 6-inch cylindrical specimens for each test.

### A.7 FIELD GROUTING

A.7.1 Procedure. Two Halliburton Oil Well Cementing Company (HOWCO) 67-ft<sup>3</sup> capacity ribbon blenders located in the immediate vicinity of the hole collars were utilized to mix single batches of 50-ft<sup>3</sup> each. Immediately following mixing, each batch was pumped down-hole through 1 1/4-inch, inside diameter, hydrill tubing employing a HOWCO Twin-10 cementer. Holes EH-1 and EH-3 were two staged, and hole EH-5 was four staged. Each grout stage was displaced up-hole with the first stage beginning at the total depth of the hole and each succeeding stage beginning at the top of the previously injected stage. Stages were emplaced following a WOC of approximately 12 hours for the previously injected stage. Staging time varied from 1.5 to 3.0 hours.

A.7.2 Results of Tests of Field Cast Specimens. During the course of the grouting operation, grout specimens representing each stage were cast and tested on detonation date. The results of the tests performed on these specimens were as follows:

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<u>Hole No.</u>	<u>Stage No.</u>	<u>Stage Depth, ft</u>	<u>Compression Strength, psi</u>	<u>Unit Weight lb/ft<sup>3</sup></u>	<u>Pulse Velocity, fps</u>
EH-1	1	600-295	4840	151.2	10,405
	2	295-Surface	5130	150.9	10,255
EH-3	1	600-260	4630	151.4	10,180
	2	260-Surface	4420	149.7	10,200
EH-5	1	1200-833	5280	152.0	10,220
	2	833-643	5370	150.8	10,100
	3	643-100	5280	151.1	10,030
	4	100-Surface	4310	151.5	9,965

### A.8 CONCLUSION

All instrument holes were successfully instrumented and grouted without any major difficulties. The grouting operation was judged to be highly successful in every respect.

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## **REFERENCES**

1. F.M. Sauer, et al; "Nuclear Geoplosics"; DASA-1285 (IV), May 1964; Stanford Research Institute, Menlo Park, California, and Defense Atomic Support Agency, Washington, D.C. 20301; Unclassified.
2. A.J. Chabai, et al; "Close-In Phenomena of Buried Explosions"; SC-4907 (RR), May 1963; Sandia Corporation, Albuquerque, New Mexico, 87116; Unclassified.



Defense Special Weapons Agency  
6801 Telegraph Road  
Alexandria, Virginia 22310-3398

AD 372807

TRC

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER  
ATTENTION: OMI/Mr. William Bush

SUBJECT: Declassification of VUP-2701

The Defense Special Weapons Agency and Defense Advanced Research Projects Agency have reviewed and declassified the following report:

VUP-2701  
VELA UNIFORM PROJECT LONG SHOT, Project 1.01,  
Ground and Water Shock Measurements, Issuance  
date 19 April 1966, Project Officer, J. D. Day,  
U. S. Army Engineer Waterways Experiment Station,  
Vicksburg, Mississippi 39181.

Since this office has no record of DTIC receiving a copy of this report, a copy is included for accession.

Also note that distribution statement "A" now applies.

Attachment:  
A/S

*Ardith Jarrett*  
ARDITH JARRETT  
Chief, Technical Resource Center

copies furn of letter only:  
FC/DASIAC/KSC